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Introductory Chapter: Recent Advances

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Chapter 1

Introductory Chapter: Recent Advances

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This book proposes the most important researches in electrical resistivity and conductivity modeling, measurement, estimation and sensing methods, and implications. Electrical conductivity and electrical resistivity are very important properties for different materials. The goal of the book achieved via presenting new and modern case studies for sensing methods of electrical resistivity, resistivity modeling of frozen soil, measurement of the electrical resistivity for unconventional structures, estimation of hydrological parameters from geoelectric measurements, and assessment of cryoprotectant concentration by electrical conductivity measurement. It presents different methods to measure resistivity for both liquid and solid materials by explaining two, three, and four pole as well as toroidal resistivity cells. The special case of sheet material resistivity and resistance is explained in more detail, and equation for that special problem is simplified. It further provides information on common experimental errors, and a short guideline to improve the reliability and accuracy of the measurements. The way to experimentally determine the cell constant of a cell is described and the necessity for calibration is clearly explained too. Also, it provides information to overcome the standard problem of polarization, when the resistivity of solutions with high ionic content is investigated. After that, it explores the conduction characteristics of permafrost. A theoretical model and an experimental study to analyze the factors affecting the resistivity of permafrost are established and implemented. The study region was the permafrost degeneration area in the Northeast China. A permafrost profile map was drawn based on data from engineering drilling and an analysis of factors that influence permafrost resistivity. The reliability of the permafrost profile map was verified by an analysis of temperature data taken at measured points at different depths of the soil profile. Then, it introduces a device for measurement of the concrete structures' electrical volume resistivity. A quench protection active system (QPS) working in tandem with a superconducting coil structure (SCS), in order to prevent the damaging effects when the coil structures passing from the superconducting state in order to switch to normal-conduction state (quench), is presented as well. Moreover, it establishes experimental relationship between hydraulic transmissivity and hydraulic conductivity with Dar-Zarrouk parameter in porous media, transverse resistance (TR), in addition to a characterization of the water quality through the electrical resistivity. The determination of hydraulic transmissivity and hydraulic conductivity is important for the development and management of groundwater exploitation of the study area. Finally, it illustrates an important application of the electrical conductivity measurement in cryopreservation. Cryopreservation is the way to cool the biological materials down to dormant state at low temperatures for long-term storage. This is done in order to reduce the cryo-injury to the cells during cryopreservation, cryoprotective agents (CPAs) should be added before freezing and removed after thawing prior to cell infusion due to the cytotoxicity of CPAs. The electrical conductivity measurement is used to assess the CPA concentration in cryopreservation. Measurement of electrical conductivity is validated as a safer and easier way to online and real-time monitoring of CPA concentration in cell suspensions, as well. Electrical resistivity and conductivity are proposed recently adopted different techniques and trends like: determining the magnitude of soil [1], in investigating frozen soil at Canada [2], in exploring frozen and petroleum polluted soils [3], in examining unfrozen water with ice substance with testing and algebraic equation implementation [4], in checking silty mud at various temperatures [5], in utilizing and examining the spatial appropriation of the island-shaped permafrost layer [6], in investigating the index of chemical weathering [7], in making initial experiments to make a relation in other different natural soil parameters using 79 samples of soil extracted from 10 boreholes [8], in illustrating and correlating clayey-soils' properties using 54 soil samples [9], and different techniques are adopted to estimate the content of water in soil with the aid of efficient electrical resistivity survey [10].

Finally, the rest of the book's chapters with their brief descriptions are shown in the following:

The second chapter, "Electrical Resistivity Sensing Methods and Implications," introduces basic operating principles of different methods to measure resistivity for both liquid and solid materials. It illustrates two, three, and four pole as well as toroidal resistivity cells. The van der Pauw technique is used as a step by step procedure to estimate the resistivity of a material with no arbitrary shape. The special case of sheet material resistivity and resistance is explained in more detail and equation for that special problem is simplified. It further provides information on common experimental errors and a short guideline to improve the reliability and accuracy of the measurements. The implications and challenges faced during resistivity measurements are explored and explained with ways to compensate for errors due to temperature and capacitance changes. In addition, the way to experimentally determine the cell constant of a cell is described and the necessity for calibration is clearly explained. It further provides information to overcome the standard problem of polarization when the resistivity of solutions with high ionic content is investigated.

The third chapter, "Resistivity Model of Frozen Soil and High-density Resistivity Method for Exploration," explores the conduction characteristics of permafrost. A theoretical model and an experimental study to analyze the factors affecting the resistivity of permafrost are established and implemented. The experimental study results are used to validate the rationality of the model of permafrost resistivity. To analyze differences in conductivity between underground media, a high-density resistivity (HDR) method is used, which infers the storage of underground geologic bodies with different resistivity based on the distribution of a conduction current under the electric field action. The study region was the permafrost degeneration area in the Northeast China. A permafrost profile map was drawn based on data from engineering drilling and an analysis of factors that influence permafrost resistivity. The reliability of the permafrost profile map was verified by an analysis of temperature data taken at measured points at different depths of the soil profile.

The fourth chapter, "Measurement of the Electrical Resistivity for Unconventional Structures," presents an apparatus for measurement of the concrete structures' electrical volume resistivity to operate at 500 Hz, within range of 5–100 Ω m for probe/concrete sample's interface. Also, a quench protection active system (QPS) working in tandem with a superconducting coil structures (SCS), in order to prevent the damaging effects when the coil structures passing from the superconducting state in order to switch to normal conduction state (quench), is presented. This chapter proposes experimentation of yttrium barium copper oxide (YBCO) tape's SCS with high temperature superconductor (HTS) type at 92 K temperature value as well. Finally, it shows measurement of the electrical resistance of the sensing element (SE) as a part of the resistive type gas sensor.

The fifth chapter, "Estimation of Hydrological Parameters from Geoelectric Measurements," proposes to establish an empirical relationship between hydraulic transmissivity (T) and hydraulic conductivity (K) with Dar-Zarrouk parameter in porous media, transverse resistance (TR), in addition to a characterization of the water quality through the electrical resistivity. This parameter is estimated from surface resistivity measurements, which are more economical in relation to the pumping tests, thus T was characterized in the study area. The reasons behind that are: in the coastal aquifer of the lower part of the right bank of the river Sinaloa, there is a need for fresh water for agricultural development because around 15% of the water used in agricultural irrigation is from underground sources. This situation is exacerbated during periods of drought, which promotes drilling with the risk of finding brackish water in them, besides this, there is the risk of not meeting water demand due to low hydraulic transmissivity (T) of the aquifer, putting at risk the drilling costs implied. In this sense, the determination of T and K (hydraulic conductivity) is important for the development and management of groundwater exploitation of the study area. Generally, by means of pumping tests in wells T is obtained, with high costs, so there are few values of T. K is generally obtained by wells and laboratory test.

The sixth chapter, "Assessment of Cryoprotectant Concentration by Electrical Conductivity Measurement and its Applications in Cryopreservation," presents an important application of the electrical conductivity measurement in cryopreservation. Cryopreservation is the way to cool the biological materials down to dormant state at low temperatures (such as −80 or −196°C, the temperature of liquid nitrogen) for long-term storage and later thaw them back to the normal physiological temperatures before usage with recovered viability and functionalities of the cells and tissues. In order to reduce the cryo-injury to the cells during cryopreservation, cryoprotective agents (CPAs) should be added before freezing and removed after thawing prior to cell infusion due to the cytotoxicity of CPAs. In this chapter, the electrical conductivity measurement was applied to assess the CPA concentration in cryopreservation. The standard correlations between the CPA concentration and the electrical conductivity of the solutions (including CPA-NaCl-water ternary solutions and CPA-albumin-NaCl-water quaternary solutions) were experimentally obtained for a few mostly used CPAs, including dimethyl sulfoxide (DMSO or Me2SO), ethylene glycol (EG), and glycerol. Then, a novel "dilution-filtration" system with hollow fiber dialyzer was designed and applied to remove the CPA from the solutions effectively. Measurement of electrical conductivity was validated as a safer and easier way to online and real-time monitoring of CPA concentration in cell suspensions.

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